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Mr. Chairman and Members of the Subcommittee, I appreciate the opportunity to testify on the Department of Energy's (DOE or Department) Hydrogen Program. Today, I will provide an overview of the program, summarize progress in implementing the recommendations of the National Academies' hydrogen report, discuss support for state initiatives and demonstration projects, as well as provide a status of the Hydrogen Program's accomplishments and plans.

Over two years ago, in his 2003 State of the Union address, President Bush announced the Hydrogen Fuel Initiative to reverse America's growing dependence on foreign oil by developing the hydrogen technologies needed for commercially-viable fuel cells – a way to power cars, trucks, homes, and businesses that could also significantly reduce criteria pollutants and greenhouse gas emissions. Since the launch of the five-year, $1.2-billion research initiative, we have had many accomplishments on the path to taking hydrogen and fuel cell technologies from the laboratory to the showroom in 2020, following an industry commercialization decision in 2015.

Our Hydrogen Program emphasizes the research and development (R&D) activities necessary to achieve the President's vision of a hydrogen economy and to address foreign oil dependence and greenhouse gas emissions. Our R&D efforts address the critical path barriers to the hydrogen economy. As an extension of these research activities, we have also established a 50-50 cost-shared partnership with industry to create a "learning" demonstration. These demonstration projects ensure that the automotive and energy industries will work together to integrate vehicle and infrastructure technologies prior to market introduction.

Drivers for Hydrogen Research: Energy and Environment

As a Nation, we must work to ensure that we have access to energy that does not require us to compromise our economic security or our environment. Hydrogen offers the opportunity to end petroleum dependence and virtually eliminate transportation-related criteria and greenhouse gas emissions by addressing the root causes of these issues. Imported petroleum already supplies more than 55 percent of U.S. domestic needs and

those imports are projected to increase to more than 68 percent by 2025 with business-as-usual. Transportation accounts for two-thirds of the oil use in the United States and vehicles contribute to the Nation's air quality problems and greenhouse gas emissions because they release criteria pollutants and carbon dioxide.

At the G8 Summit earlier this month, President Bush reiterated his policy of promoting technological innovation, like the development of hydrogen and fuel cell technologies, to address climate change, reduce air pollution and improve energy security in the United States and throughout the world. The Department's R&D in high-efficiency vehicle technologies, such as gasoline hybrid-electric vehicles, will help improve energy efficiency and reduce the growth of petroleum consumption in the nearer term. Under DOE's FreedomCAR Program, the President's FY 2006 budget request is $100.4 million. This funding will make hybrid-vehicle components, like batteries, power electronics, electric motors and advanced materials, more affordable. But, in the longer term, higher efficiency alone will not reduce our petroleum consumption; we ultimately need a substitute to replace petroleum. Hydrogen and fuel cells, when combined, have the potential to provide domestically-based, virtually carbon- and pollution-free power for transportation.

Hydrogen can be produced from diverse domestic energy resources, which include fossil fuels, nuclear energy, biomass, solar, wind and other renewables. We have planned and are executing a balanced research portfolio for developing hydrogen production and delivery technologies. Hydrogen from coal will be produced directly by gasification—not coal-based electricity. For hydrogen from coal to be viable, research in carbon capture and sequestration technologies must also be successful. The ultimate outcome we are seeking is hydrogen from carbon-neutral fossil, nuclear and renewable energy resources.

In the transition to the hydrogen economy, the Department recognizes that hydrogen will be produced by technologies that do not require a large, up-front investment in hydrogen delivery infrastructure. Instead, hydrogen can be produced at the refueling station by reforming natural gas and renewable fuels like ethanol utilizing existing delivery infrastructure. A fuel cell vehicle running on hydrogen produced from natural gas would produce 25 percent less net carbon emissions than a gasoline hybrid electric vehicle and 50 percent less than conventional internal combustion engine vehicles on a well-to-wheels basis. However, natural gas is not a long-term strategy because of concerns of limited supply and the demands of other sectors. As vehicle market penetration increases and research targets for the diverse hydrogen production and delivery technologies are met, these will help establish the business case for industry investment in large-scale hydrogen production and delivery infrastructure.

Major Challenges to the Hydrogen Economy

The President's FY 2006 request to Congress for the Hydrogen Fuel Initiative is $259.5 million. This funding is necessary to conduct the research to overcome the barriers to the hydrogen economy:

- The technology must be developed to store enough hydrogen on-board a vehicle to enable greater than 300-mile driving range without reducing cargo or passenger space.

- The high-volume cost of the fuel cell system must be reduced by a factor of seven in order to be competitive with today's internal combustion engines, and durability needs to be improved by a factor of five.

- The cost of producing hydrogen must be reduced to be competitive with the cost of gasoline. Hydrogen from natural gas reforming is currently about two times as costly as gasoline (untaxed) and hydrogen from other sources (renewables, nuclear energy and coal combined with sequestration) is even more costly.

- Improved materials and system designs must be developed to ensure the safe use of hydrogen. Codes and standards need to be developed to enable implementation of hydrogen technologies, and international standards are needed to eliminate trade barriers.

- Educational materials must be developed and available for key target audiences (e.g. first responders, etc.) to understand hydrogen and fuel cell technologies and their uses.

Progress and Accomplishments

Mr. Chairman, the Department has made significant progress in planning and setting the stage to achieve the research breakthroughs necessary for a future hydrogen economy. The Department has competitively selected over $510 million in projects to address critical challenges such as hydrogen storage, fuel cell cost and durability, and hydrogen production and delivery cost. In addition, we have established a national "learning" demonstration and new projects in safety, codes and standards, and education. All of the multi-year projects discussed below were competitively selected and are subject to congressional appropriations. The continuum of research, from basic science to technology demonstration, will be closely coordinated.

- In May 2005, 70 new projects were selected at $64 million over three years to focus on fundamental science and to enable revolutionary breakthroughs in hydrogen production, storage and fuel cells. Topics of this basic research include novel materials for hydrogen storage, membranes for hydrogen separation and purification, designs of catalysts at the nanoscale, solar hydrogen production, and bio-inspired materials and processes.

- Three Centers of Excellence and 15 independent projects were initiated in Hydrogen Storage at $150 million over five years to develop the most promising low-pressure storage approaches. The Centers include 20 universities, 9 federal laboratories and eight industry partners, representing a concerted, multi-disciplinary effort to address on-board vehicular hydrogen storage.

- To address fuel cell cost and durability, five new projects were initiated at $13 million over three years. A $17.5 million solicitation is currently open to research new membrane materials in fuel cells. And, a new $75 million solicitation will be released this fall to address cost and durability of fuel cell systems.

- A total of 65 projects were awarded for applied research in hydrogen production and delivery, funded at $107 million over four years. These include hydrogen production from renewables, distributed natural gas, coal and nuclear energy.

- A national vehicle and infrastructure "learning demonstration" project, a six-year effort with $170 million in DOE funding, was launched to take research from the laboratory to the real world, critically measuring progress and providing feedback to our R&D efforts.

- Approximately $7 million over four years for hydrogen education development was awarded to serve the needs of multiple target audiences, including state and local government officials, safety and code officials and local communities where hydrogen demonstrations are located.

With these new competitively selected awards, the best scientists and engineers from around the Nation are actively engaged. The stage is now set for results.

Our ongoing research has already led to important technical progress.

- As highlighted by Secretary Bodman in earlier Congressional testimony, the high-volume cost of automotive fuel cells was reduced from $275 per kilowatt to $200 per kilowatt in two years. This cost reduction was the result of increased power density; advancements in membrane materials; reductions in both membrane material cost as well as amount of membrane material required in the fuel cell; enhancement of specific activity of platinum catalysts; and innovative processes for depositing platinum and reducing the overall amount of catalysts.

- In hydrogen production, we have demonstrated our ability to produce hydrogen at a cost of $3.60 per gallon of gasoline equivalent at an integrated fueling station that generates both electricity and hydrogen. This is down from about $5.00 per gallon of gasoline equivalent prior to the Initiative.

Implementation of National Academies' Recommendations

We have implemented the valuable feedback from the National Academy of Sciences (NAS) review in March 2004 and are already seeing results. The NAS called for us "to improve integration and balance of activities" within the relevant DOE Offices (which include Energy Efficiency and Renewable Energy; Fossil Energy; Nuclear Energy, Science and Technology; and Science). We have done this by developing and publishing an integrated research, development and demonstration plan, called the "Hydrogen

Posture Plan," which covers all Department hydrogen activities. The Plan identifies the major milestones which need to be achieved to enable industry to make a 2015 commercialization decision. Each of the four offices has, in turn, developed a detailed research plan which outlines how the high-level milestones will be supported. Lower-level, time-phased, performance-based milestones form the basis for measuring research progress.

In response to another National Academies' recommendation, we established a systems analysis activity to examine the impact of different components or subsystems of hydrogen technology on the complete system, as well as establish the time frames needed for transition to a hydrogen economy. "Well-to-wheels" analyses assessing the energy, economic and environmental impacts of various hydrogen production and delivery pathways, as well as other systems analysis activities, will be valuable in technology decision-making and planning for a transition to the hydrogen economy.

The Hydrogen Program has increased emphasis on exploratory research in response to the NAS recommendation that "there should be a shift … away from some development areas towards exploratory work" and that "the probability of success [will be] greatly increased by partnering with a broader range of academic and industrial organizations." In accordance with this recommendation, we have moved away from subsystem hardware development, such as fuel cell stack systems and conventional high-pressure storage tanks, to put greater emphasis on materials research.

Starting in FY 2005, DOE's Office of Science has been included in the Hydrogen Fuel Initiative in order to focus basic research on overcoming key technology hurdles in hydrogen production, storage and conversion. The Office of Science-funded research seeks fundamental understanding in areas such as novel materials for hydrogen storage with an emphasis on nanoscale structures and new storage concepts, non-precious-metal catalysts, membranes for fuel cells and hydrogen separation, multifunctional nanoscale structures, photocatalytic (including biological and bio-inspired approaches) and photoelectrochemical hydrogen production, and modeling and analytical tools. The three Centers of Excellence established through the Department's "Grand Challenge" solicitation are utilizing recent progress in materials discovery and technology which allows hydrogen to be stored at low pressures and modest temperatures. Rather than "stand alone" test tube research, we have an integrated effort to address basic, applied, and engineering sciences to develop materials and systems for storing hydrogen.

Through the hydrogen production solicitations, we have increased emphasis on long-term research. Last October, DOE announced industry and university grants of $25 million over three years, contingent upon appropriations, for solar-driven photoelectrochemical, thermochemical and photobiological technology. The NAS also recommended changes in other hydrogen production technology areas and advised DOE to "increase development of breakthrough approaches for small-scale reformers [,] …research novel renewable liquid distributed reforming [and]…emphasize electrolyzer development." Our transition strategy emphasizes small-scale reformers and electrolyzers for refueling stations and distributed electricity generation sites. Through our solicitation, we have

added new projects totaling $30 million over 3 years, contingent upon appropriations, in these areas. We have worked with our energy industry partners to develop technology roadmaps that emphasize distributed technologies.

Collaboration through Partnerships

We are working with partners on all fronts to address the challenges to a hydrogen economy. Under the FreedomCAR and Fuel Partnership, DOE is collaborating with the U.S. Council for Automotive Research (DaimlerChrysler, Ford and General Motors) and five major energy companies (BP, Chevron, ConocoPhillips, ExxonMobil and Shell) to help identify and evaluate technologies that will meet customer requirements and establish the business case. Technical teams of research managers from the automotive and energy industries and DOE are meeting regularly to establish and update technology roadmaps in each technology area.

An Interagency Hydrogen R&D Task Force has been established by the White House Office of Science and Technology Policy (OSTP) to leverage resources and coordinate interrelated and complementary research across the entire Federal Government. This year, the Task Force initiated a plan to coordinate a number of key research activities among the eight major agencies that fund hydrogen and fuel cell research. Coordination topics include novel materials for fuel cells and hydrogen storage, inexpensive and durable catalysts, hydrogen production from alternative sources, stationary fuel cells, and fuel-cell vehicle demonstrations. The Task Force has launched a website, Hydrogen.gov, and in the coming year plans to sponsor an expert panel on contributions that nanoscale research can make to realizing a hydrogen economy.

Last year, we announced the establishment of the International Partnership for the Hydrogen Economy (IPHE). The IPHE, which now includes 16 nations and the European Commission, establishes world-wide collaboration on hydrogen technology. The members have agreed to work cooperatively toward a unifying goal: practical, affordable, competitively-priced hydrogen vehicles and refueling by 2020. Projects involving collaboration between different countries are being proposed and reviewed for selection.

State Initiatives and Demonstration Projects

The Department supports the growing number of state hydrogen initiatives by providing accurate and objective information about hydrogen and fuel cell technologies. Hydrogen initiatives exist in more than ten states, including California. The Department is a member of the California Fuel Cell Partnership and has participated on planning committees for the California Hydrogen Highway Network. Today, 21 full members and ten associate members representing eight automakers, four fuel providers, the supplier industry, as well as state and Federal Government agencies (including DOE, DOT, and EPA), are working together through the Partnership to share their experiences operating first-of-their-kind research vehicles throughout California. The objective of the new

Hydrogen Highway Network initiative, championed by Governor Schwarzenegger, is to ensure that hydrogen fuel availability will match fuel cell vehicle demand.

As mentioned earlier, the Department's partnership with the automotive and energy industries to conduct a national "learning" demonstration project will expand the Program's research while leveraging industry investments in hydrogen and fuel cell technologies; subject to appropriations, the first phase of the project will total over $350 million, with more than 50 percent coming from industry. The project includes four automotive and energy teams made up of General Motors and Shell; Ford and BP; DaimlerChrysler and BP; and Chevron and Hyundai-Kia.

The goals of the project are:

- to obtain detailed component and performance data to guide the Department's hydrogen and fuel cell research, and
- to validate industry's progress toward meeting the milestones leading up to the 2015 commercialization decision.

Three major milestones for 2009, when phase one ends, are: 2,000-hours fuel cell durability; 250-mile vehicle range; and $3.00 per gallon gasoline equivalent hydrogen fuel.

While hydrogen fuel infrastructure and fuel cell vehicle technologies are not ready for widespread deployment or commercialization, DOE believes there is tremendous benefit in energy and auto companies working together before the market introduction phase to ensure that there is seamless integration. Transitioning to a hydrogen-based infrastructure from today's petroleum infrastructure will require coordination between stakeholders. For example, standards for hydrogen purity must be addressed before commercialization can happen. Fuel cell manufacturers would like the purest hydrogen available to ensure the best performance and longest durability; however, it will not be cost-effective for energy suppliers to produce and deliver perfectly pure, laboratory-grade hydrogen. Therefore, some compromise must occur and the demonstration program will provide the data necessary to facilitate development of hydrogen fuel quality standards prior to commercialization and infrastructure investment.

Toward the Hydrogen Future

DOE is looking to the future as well. Just as we have already made progress, we plan to have significant progress next year. The progress will be tracked using performance-based technical and cost milestones that provide clear and quantifiable measures. We will report this progress annually to Congress and to the Office of Management and Budget.

For our critical targets, it is important that we verify our progress in a way that is independent and transparent. In Fiscal Year 2006, three major technical milestones will be assessed using independent review:

- In hydrogen storage, we will determine the potential of cryogenic-compressed hydrogen tanks to meet DOE's 2010 targets.
- In fuel cells, we will evaluate high-volume fuel cell cost per kilowatt against our 2006 target of $110 per kilowatt and towards meeting the 2010 target of $45 per kilowatt.
- In hydrogen production, we will determine if the laboratory research is complete for $3.00 per gallon gasoline equivalent with distributed natural gas reforming technology. This technology will need to be validated later at full-scale.

In addition, high-volume manufacturing processes must be developed to lower the costs of hydrogen and fuel cells. Manufacturing R&D challenges for a hydrogen economy include developing innovative, low-cost fabrication processes for new materials and applications as well as adapting laboratory fabrication techniques to enable high-volume manufacturing. The Hydrogen Program is working with the Department of Commerce and other Federal agencies to create a roadmap for developing manufacturing technologies for hydrogen and fuel cell systems as part of the President's Manufacturing Initiative. The roadmap will help to guide budget requests in Fiscal Year 2007 and beyond. This work is part of the Interagency Working Group on Manufacturing R&D, which is chaired by the Department of Commerce and includes 14 Federal agencies. The Working Group has identified three focus areas for the future: nano-manufacturing, manufacturing R&D for the hydrogen economy, and intelligent and integrated manufacturing systems. Manufacturing R&D for the hydrogen economy will be critical in formulating a strategy to transfer technology successes in the laboratory to new jobs, new investments and a competitive U.S. supplier base in a global economy.

Successful commercialization of hydrogen technologies requires a comprehensive database on component reliability and safety, published performance-based domestic standards, and international standards or regulations that will allow the technologies to compete in a global market. Initial codes and standards for the commercial use of hydrogen are only now starting to be published. Research will be conducted in Fiscal Year 2006 to determine flammability limits under real-world conditions and the dispersion properties of hydrogen under various conditions and also to quantify risk. Through such efforts, critical data will be generated to help write and adopt standards and to develop improved safety systems and criteria. DOE is also working closely with the Department of Transportation in hydrogen codes and standards.

Conclusion

Mr. Chairman, the Department of Energy welcomes the challenge and opportunity to play a vital role in this Nation's energy future and to help address our energy security challenges in such a fundamental way. This completes my prepared statement. I would be happy to answer any questions you may have.